INTERNAL RETURN IN THE CUBYLCARBINYL SYSTEM

A THESIS

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BY

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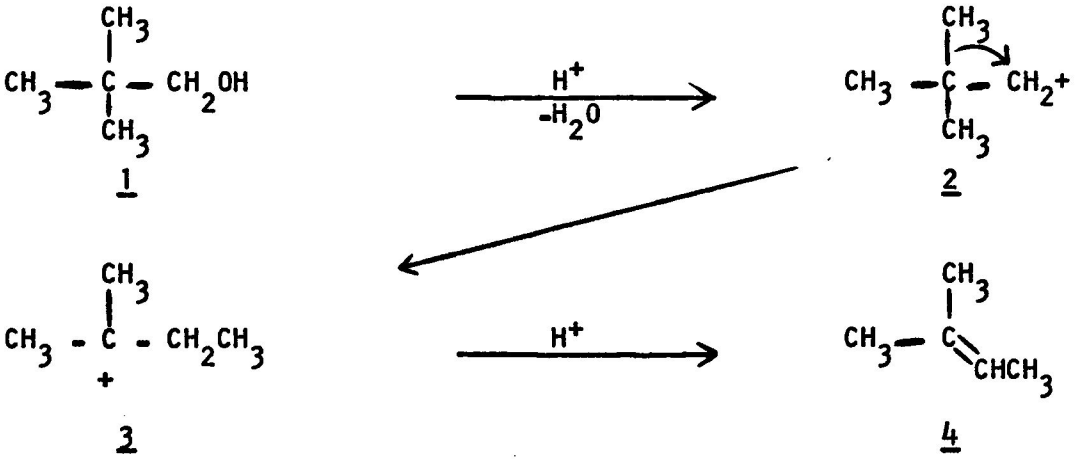
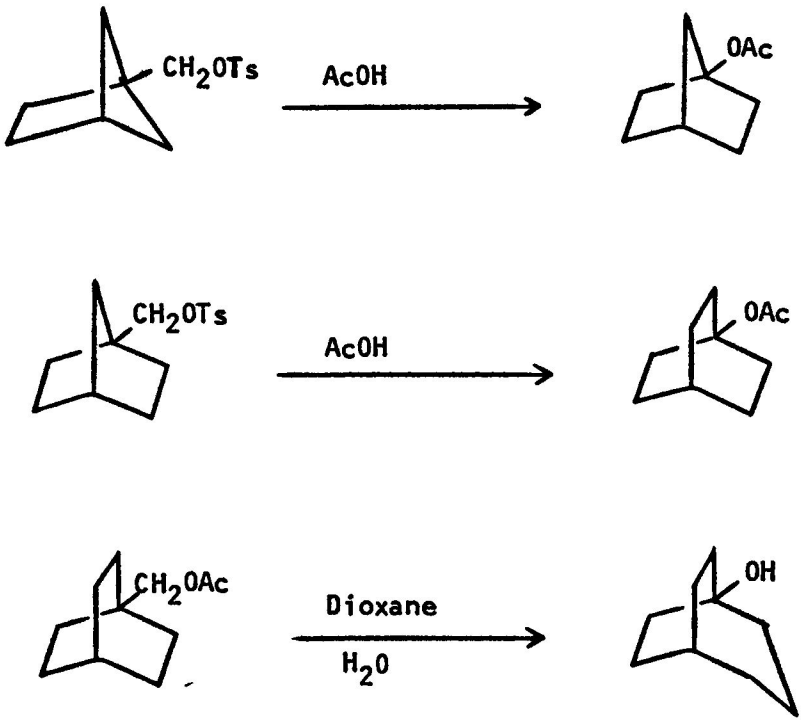
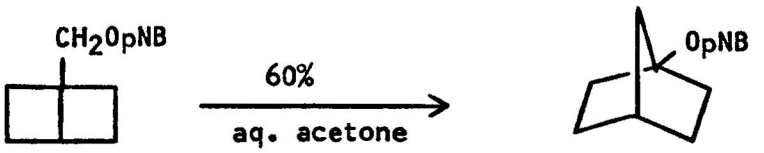
INTRODUCTION

One of the most fascinating aspects of the chemistry of the carbonium ions is the propensity of these electron deficient species to stabilize themselves by rearrangement. The driving force for rearrangement may be due to relief of ring strain, formation of a more stable ion or a combination of effects. The classical example of reactions of this type is that which involves a 1,2-alkyl shift, or Wagner-Meerwein rearrangement.[1] For example, in the acid catalyzed dehydration of neopentyl alcohol (1), trimethylethylene (4) is the major olefinic product.[1] The overall transformation can be envisioned as proceeding through the primary ion 2 which undergoes a 1,2-methyl shift to form the more stable tertiary-amyl ion 3. Loss of a proton from 3 yields trimethylethylene. Alternatively, methyl migration and loss of water could be concerted giving rise to the tertiary-amyl cation 3 directly. Results from the solvolysis of neopentyl derivatives suggest that the concerted mechanism is operative in these reactions.[2] By analogy it might be expected that a similar mechanism is involved in the rearrangement of related carbinyl systems.

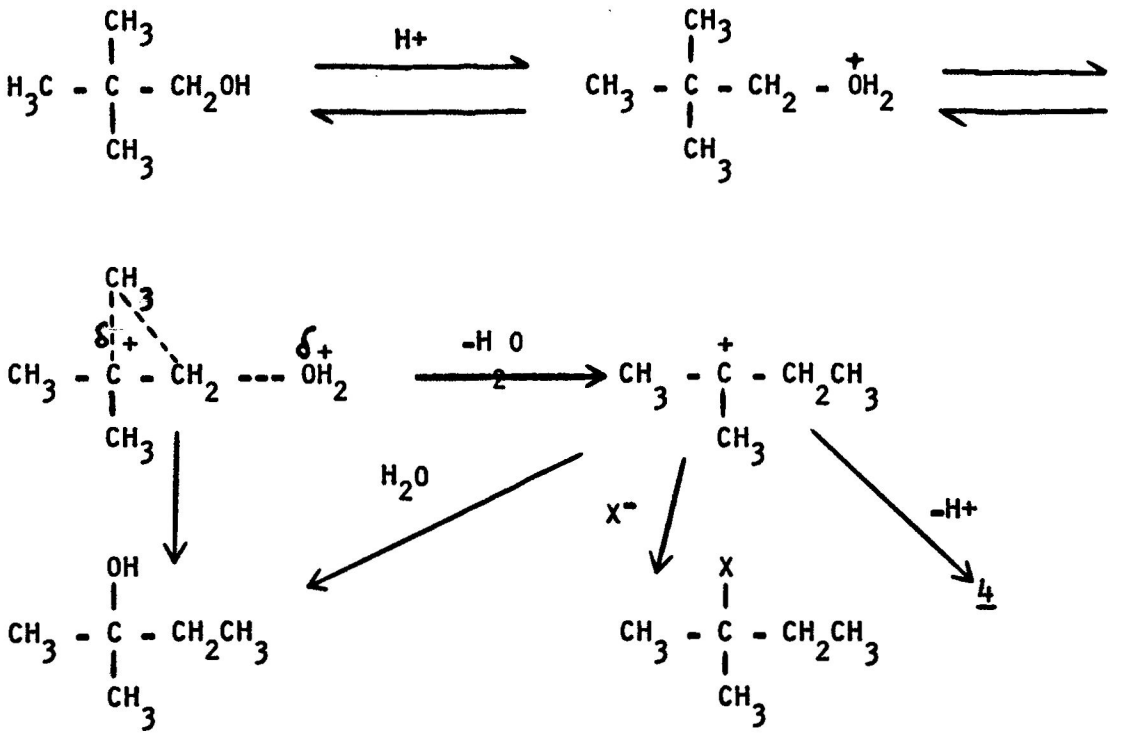


Wagner-Meerwein rearrangements have been observed in the solvolysis of other carbinyl derivatives where formation of an ion at the reaction center would yield a primary carbonium ion. With a strained ring system one of the driving forces toward rearrangement is the relief of ring strain. Some examples include the following:[3,4]

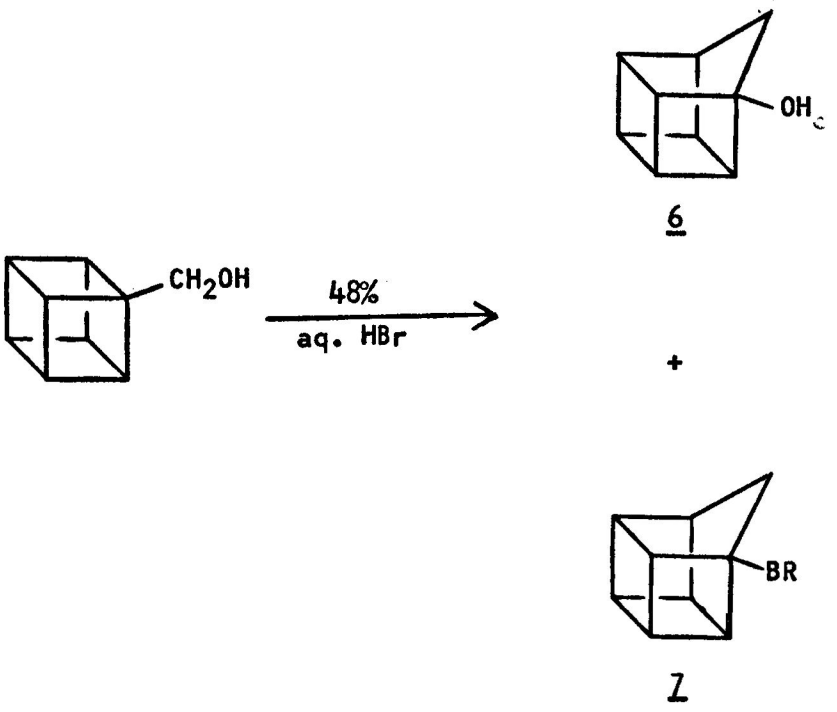




In many solvolytic reactions involving 1,2-alkyl shifts, including the ones cited above, products resulting from internal return of the leaving group as well as that derived from attack of the solvent at the carbonium ion center are formed. A more general mechanism for this reaction that can account for rearrangement, internal return, and attack of other nucleophiles is illustrated below with neopentyl alcohol as an example:

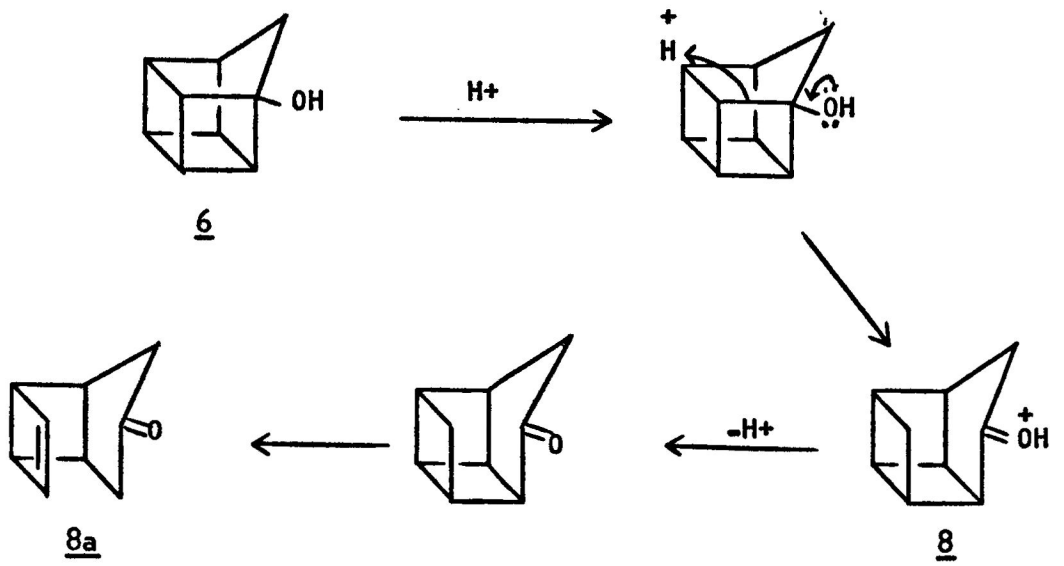


A considerable amount of evidence has been obtained to support the general scheme outlined above.[2] In the cubylcarbinyl system, rearrangement and internal return of the leaving group dominate the reactions. For example, when cubylcarbinol (5) is treated with 48 per cent aqueous hydrogen bromide at room temperature, homocubyl alcohol (6) and homocubyl bromide (7) are formed. The fact that the cubylcarbinyl system rearranges to the more stable homocubyl system is not surprising. However, alcohol 6 predominates two to one even when excess bromide ion is used.



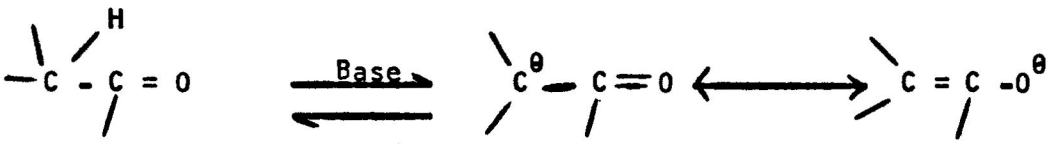
When cubylcarbinol was refluxed with aqueous hydrogen bromide a new product, tentatively identified as the ketone 8 was isolated.[5] The ketone was formed in the same ratio to the homocubyl bromide (7) as the alcohol 6 was in the reaction at room temperature. Evidence which

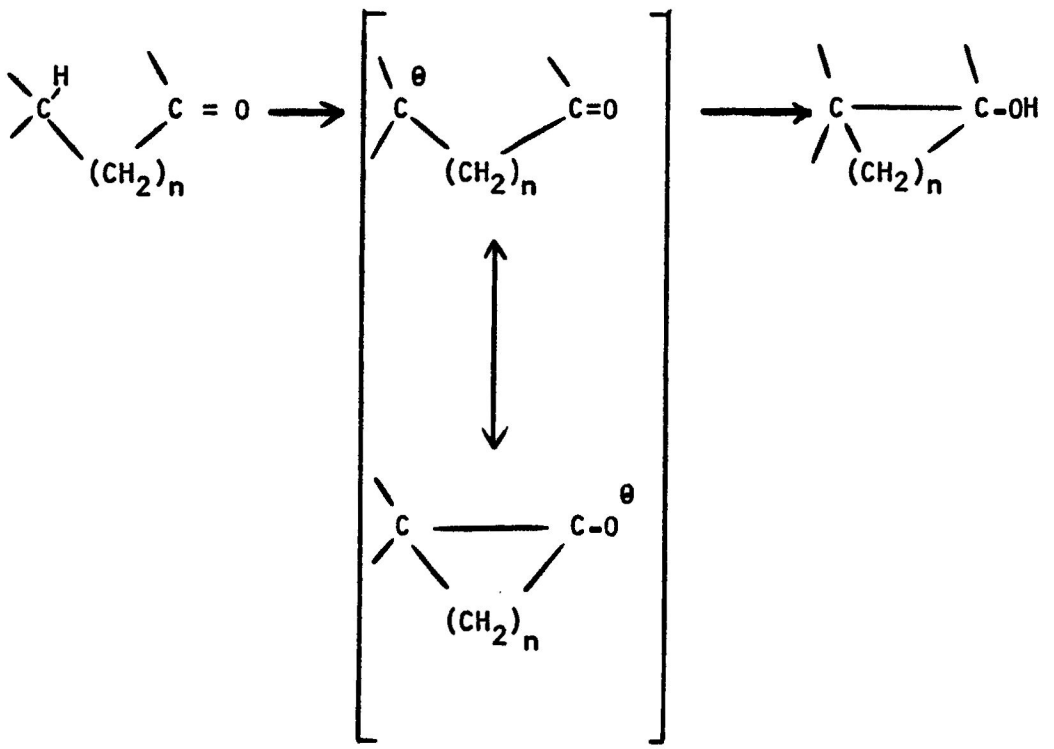
supported the existence of this ketone was a carbonyl absorption band found in the infrared spectrums at λ= 5.71 and 5.86 (sh) mμ. Mass spectral data showed a parent molecule ion at m/e 215,[5] consistent with addition of one mole of hydrogen bromide to cubylcarbinol (5). It was presumed that homocubyl alcohol (6) had been converted to the ketone which subsequently added a mole of hydrogen bromide. A possible explanation for this conversion is homoketonization of homocubyl alcohol as shown below. The ketone 8 can conceivably further rearrange to give the eneone 8a which can add a mole of hydrogen bromide.



Homoketonization and homoenolization have been reported by Nickon.[6] Homoenolization takes place when a hydrogen is abstracted from a beta or a higher position and the resulting anion is stabilized by homoconjugation. Normal enolization takes place in acidic or basic solution when there is a hydrogen alpha to the carbonyl group.

If we have a system such as the one diagrammed below in which there are no alpha hydrogens, hydrogen abstraction must come from a beta or higher position. This would set up the enolate anion shown below, stablized by homoconjugation.

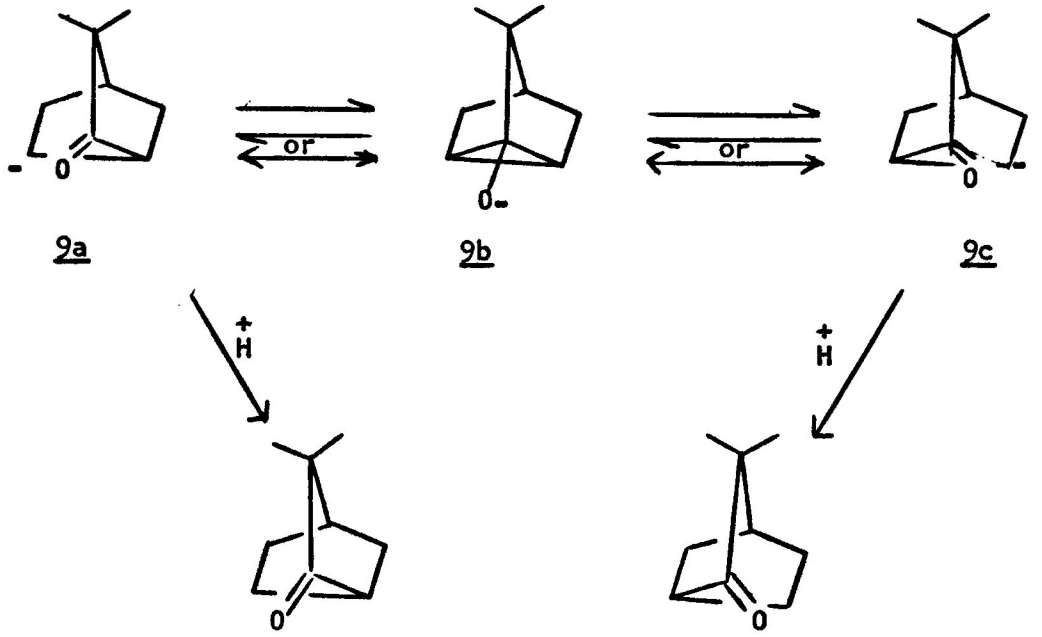




I

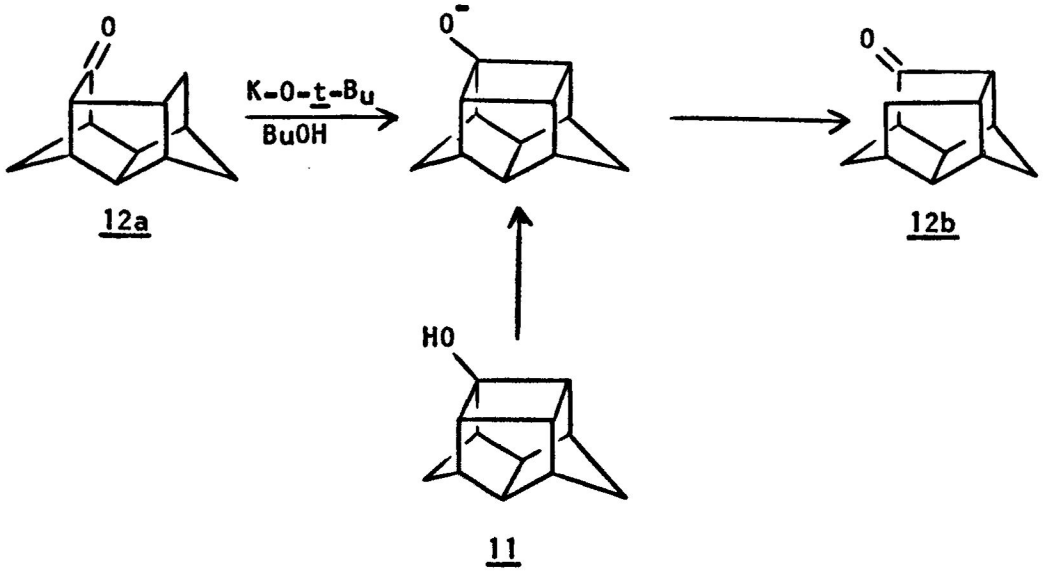
Such an ion (I) is termed homoenolate. The enol produced would be called the homoenol. All of the reactions above are reversible, therefore if one were to start with a homoenol a homoketone could be produced. To study homoenolization, Nickon[6] chose the camphenilone system (9) because it has no extractable alpha hydrogens. In this system there would be a

fifty-fifty chance of either 10a or 10b being produced.



Homoenolization would lead to racemization when camphenilone is treated with base. In his subsequent work Nickon[7] showed that original deuterium uptake exactly matched the rate of racemization. However, prolonged refluxing produced deuterium at all beta sites.

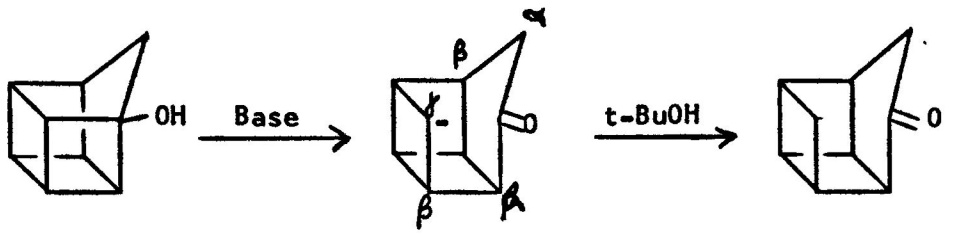
Winstein[8] and Fukunaga[9], in 1965, independently reported homoenolization and homoketonization with abstraction of a gamma hydrogen. Their work was done with the bird-cage alcohol 11. The half cadged ketone 12 was produced when 11 was treated with potassium t-butoxide in t-butanol. The proposed mechanism for this reaction is depicted as follows:



12a 12b

11

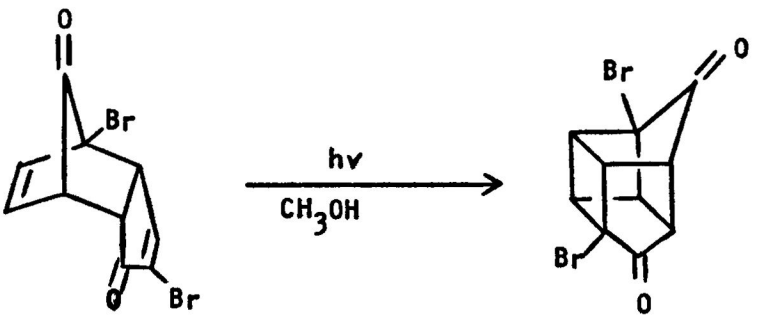
The predominant product is 12b because of the greater relief of strain. Formation of 12b indicates the abstraction of a hydrogen from the gamma position as thus an anion is left in that position. The bird cage system is structurally similar to the homocubyl system in that an anion would be generated in the gamma position.



The work described in this thesis is concerned with the reactions of cubylcarbinol (5) with a variety of acids and an investigation of homoenozation of homocubyl alcohol (6).

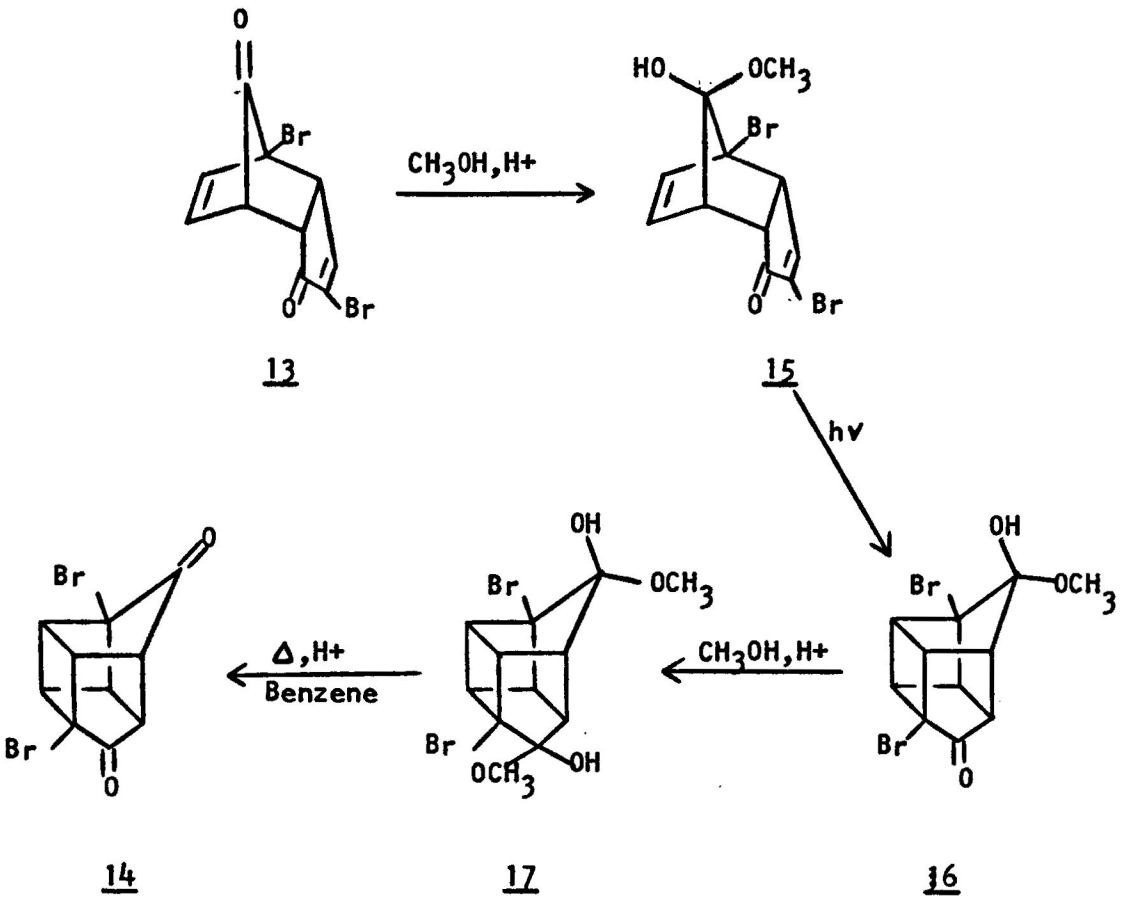
RESULTS AND DISCUSSION

Cubylcarbinol (5) was synthesized by the same procedure reported previously;[5] however, attention must be given to certain critical steps. The first of these is the photolysis of the dimer 13 to form the caged diketone 14.



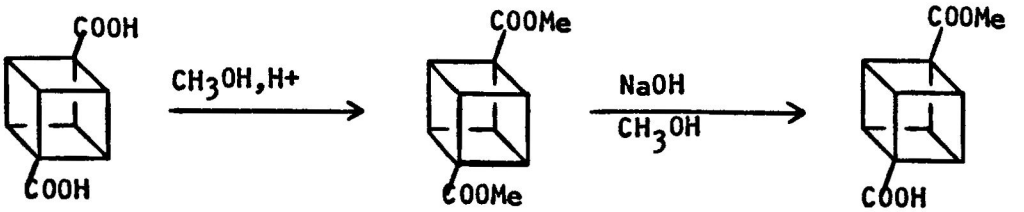
13 14

The irradiation of 13 is carried out in methanolic hydrogen chloride. The reactants must be thoroughly mixed. Failure to achieve adequate mixing will lead to a greatly reduced yield of caged diketone 14. The reaction proceeds from the dimer 13 to the hemiketal 15. The latter undergoes ring closure to the caged isomer 16 which in turn reacts with the solvent to produce the bis-hemiketal 17. The bis-hemiketal is then dehydrated for form the diketone 14. If insufficient mixing occurs polymeric ethers are formed which cannot be hydrolyzed, even when treated with concentrated hydrochloric acid or sulfuric acid.

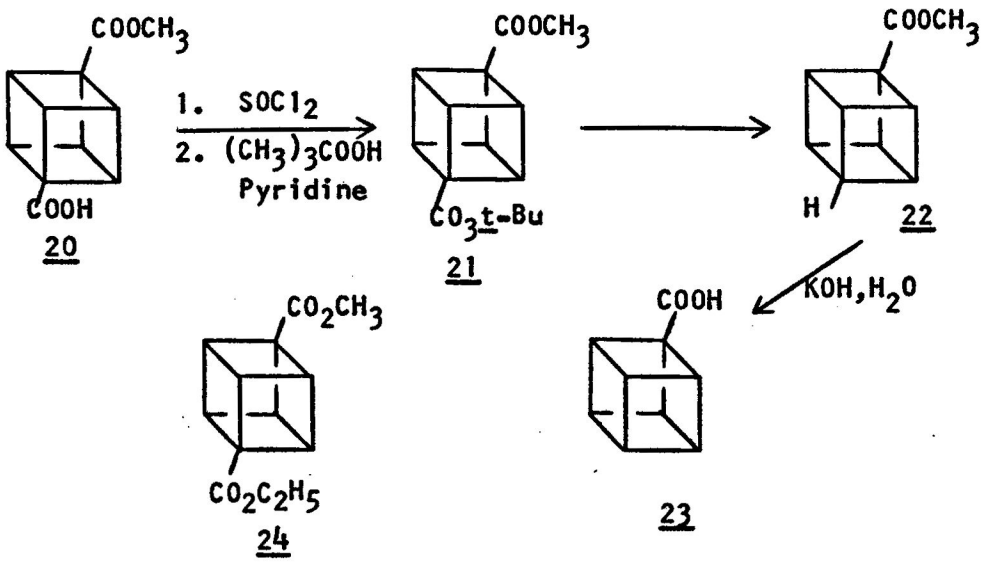


13 15 16 17 14

When the caged diketone 14 is refluxed with 25 per cent aqueous sodium hydroxide, it is converted to cubane dicarboxylic acid (18). p-Dicarboxyl cubane is taken to cubanecarboxylic acid (23) by means of the following reaction sequence:[5]



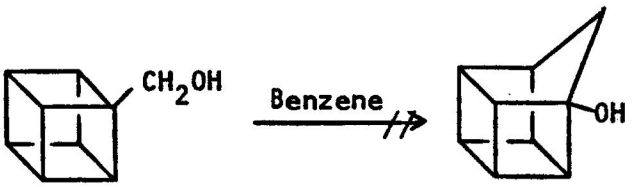
18 19 20



The second critical step that must receive special attention is the preparation of the esterperoxyester 21. In this reaction the half-acid 20 is converted to the acid chloride by several hours reflux with thionyl chloride. The acid chloride is then converted to the perester 21 with t-butyl hydroperoxide and pyridine in anhydrous ether. It is very important that the ether be throughly dried and devoid not only of all traces of water but any ethanol that might be present. If ethanol is present, the ethyl ester 24 will be formed. With two hours reflux over lithium aluminum hydride, the ether is rendered anhydrous and free of all ethanol.

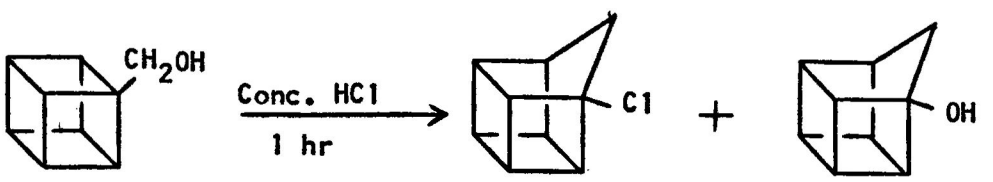
With a successful synthesis of cobylcarbinol (5) at hand, reaction conditions for preparation of its isomer, homocubylalcohol (6), in good yield were sought. It was hoped, initially, that cubylcarbinol could be isomerized directly to 6. If the alcohol was relatively unstable, it seemed reasonable to expect that rearrangement could be effected by heat and/or mild acid catalysis. However, despite prolonged reflux in benzene and toluene with and without added p-toluene sulfonic acid, cubylcarbinol remained unchanged. The cubane skeleton is apparently quite stable under

these conditions.



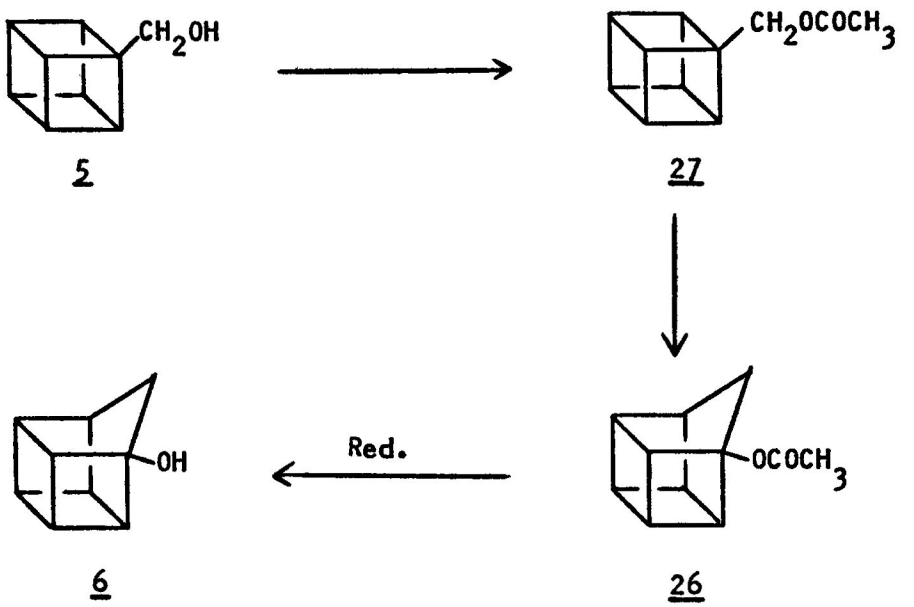
5 6

Since it has been shown that cubylcarbinol rearranges with hydrobromic acid to produce homocubyl alcohol (6) and homocubyl bromide (7), in a two to one ratio, respectively,[5] an attempt was made to use concentrated hydrochloric acid to see whether a larger ratio of alcohol to halide could be produced. Reaction of cubylcarbinol with concentrated hydrochloric acid proceeded with about 75 per cent yield and with a large ratio of alcohol 6 to chloride 25. Treatment with 10 per cent and 20 per cent aqueous hydrochloric acid solutions afforded the same ratio of alcohol to chloride (vide infra). In addition, preliminary attempts were made to determine if the ketone 8 is formed by refluxing 5 for two hours in concentrated hydrochloric acid. However, no ketone could be found upon infrared analysis of the product. Only homocubyl alcohol (6) was present.



5 25 6

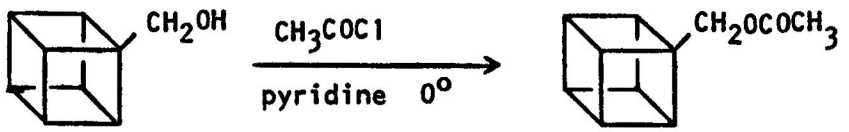
Homocubyl alcohol could not be prepared directly from cubylcarbinol without competition from side reactions. This approach was abandoned in favor of a more lengthy route that would permit complete control of each step. This sequence is shown in the following flow chart:



5 27 6 26

Preparation of the cubylcarbinyl acetate 26 was first attempted by reacting cubylcarbinol (5) with glacial acetic acid. The reaction mixture was stirred for one hour and examined by nuclear magnetic resonance spectroscopy. The spectrum depicted a large amount of starting material and only a small amount of cubylcarbinyl acetate (27). The crude reaction product was then treated with acetyl chloride at reflux for one hour. A reaction occurred immediately. A nuclear magnetic resonance spectrum of this product showed that the major product was homocubyl acetate (26) with a small amount of homocubyl alcohol and unrearranged acetate present. The yield was poor. Apparently, the hydrogen chloride liberated as by-

product catalyzed the rearrangement. Although glacial acetic acid is not effective enough to cause isomerization, the reaction is very fast with stronger acids. When cubylcarbinol (5) was treated with acetyl chloride and pyridine at 0° in ether, cubylcarbinyl acetate (27) was produced in quantitative yield without complications from formation of side products.



5 27

Cubylcarbinol (5) is stable to heat and weak acids. However, when a strong acid such as hydrochloric was used a rearrangement occurred very rapidly to give homocubyl alcohol and homocubyl chloride. Accordingly, the next step, rearrangement of the acetate 27 to homocubyl acetate 26, should proceed in strong acid. Caution had to be used because of the possibility of nucleophilic substitution by halide ion if hydrobromic or hydrochloric acid were used. When the alcohol 5 is treated with these reagants halide substitution occurs as well. Trifluoroacetic acid was chosen since it is a strong acid and if acetate exchange did occur both acetates would give the same product on reduction.

When cubylcarbinyl acetate (27) was dissolved in trifluoroacetic acid there was an immediate reaction. A nuclear magnetic resonance

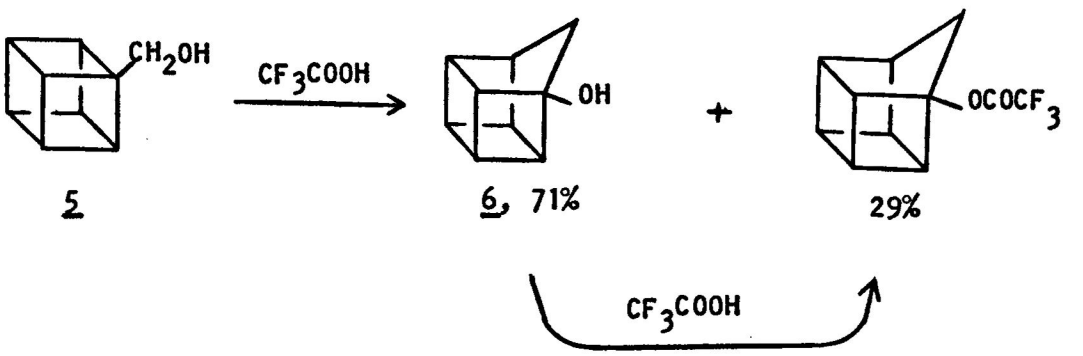
spectrum taken within ten minutes showed similarities to the spectrum of the bromide 7. The spectrum showed a broad triplet centered at δ= 3.34 ppm, a multiplet centered at δ= 3.20 ppm, and a doublet at δ= 2.10 ppm, (J = 1.2 Hz) in a ratio of 5:2:2:3, respectively. An infrared spectrum showed the trifluoroacetate absorptions at $\lambda(CCl_4)$ = 5.76 and 8.10 μ as well. Pure acetic acid, 1, 10 and 25 per cent trifluoroacetic acid in acetic acid, 32 per cent hydrogen bromide in acetic acid and water were unsuccessful at effecting the rearrangement. Rearrangement of cubylcarbinyl acetate to homocubyl acetate occurred with 100 per cent internal return in anhydrous trifluoroacetic acid.

In an attempt to determine how facile the cubylcarbinyl system rearranges, cubylcarbinol (5) was added directly to trifluoroacetic acid and the progress of the reaction was followed by nuclear magnetic resonance spectroscopy. A spectrum taken within five minutes after addition revealed a multiplet between δ= 3.4 ppm, a doublet centered at about δ= 2.1 ppm (J = 1.2 Hz) and a doublet centered at about δ= 1.9 ppm (J = 1.2 Hz). The doublets were present in a ratio of: 1: 2.5. The latter spectrum was different from the spectrum of the homocubyl derivatives previously prepared. The mixture was then heated to 60° for ten minutes and a second spectrum was recorded. This spectrum showed a broad triplet appearing at about δ= 3.8 ppm, the multiplet (between δ = 3 - 4 ppm) reducing in intensity, the doublet at about 2.1 ppm was growing while the doublet at 1.9 ppm was shrinking. After an hour at 60°, the nuclear magnetic resonance spectrum showed features similar to spectra of homocubyl derivatives. The doublet at about 2.1 ppm had become the predominant peak and the doublet at 1.9 ppm had practically disappeared.

After several hours the spectrum showed all the features of the homocubyl acetate spectrum (except for the presence of the methyl peak).

The spectrum was difficult to interpret initially. Answers became possible after a pure sample or homocubyl alcohol (6) was prepared. The spectrum of homocubyl alcohol shows a broad multiplet centered at δ = 3.29 ppm (7 cage protons + OH) and a doublet centered at δ = 2.79 ppm ($\not\subset^{H}_{H}$, J = 1.2 Hz) in a ratio of 8:2, respectively. The chemical shift of the methylene protons matched that of the first spectra in the trifluoroacetic acid reaction. The methylene protons in homocubyl alcohol have a chemical shift of 1.9 ppm while the methylene protons of other homocubyl derivatives have a chemical shift of 2.1 ppm.

Homocubyl alcohol was prepared in good yield by lithium aluminum hydride reduction of homocubyl acetate (26). The following mechanism for the reaction of cubylcarbinol with trifluoroacetic acid can now be written as follows:



The nature of the cubylcarbinyl carbonium ion was further studied using other conditions and other nucleophiles. Since a 2:1 ratio of homocubyl alcohol (6) to homocubyl bromide (7) had been obtained when cubylcarbinol was reacted with 48 per cent aqueous hydrobromic acid,[5] and since reactions with concentrated hydrochloric acid had produced large ratios of alcohol to chloride, different nucleophiles and different reaction conditions were chosen to determine if different ratios of homocubyl alcohol to substitution product would be obtained. The results of these reactions are shown in Table 1.

As indicated in Table 1, all of the reactions afforded homocubyl alcohol in approximately at least a 2:1 ratio. The reason for the seemingly large ratio of homocubyl alcohol (6) to homocubyl chloride (25) in the initial hydrochloric acid reactions became apparent when the methanolic hydrogen chloride reaction was completed. After the solvent was evaporated without changing reaction vessels, the yield was checked and found to correspond to 68 per cent of the consumed cubylcarbinol. A nuclear magnetic resonance spectrum showed only homocubyl alcohol and no homocubyl chloride. The chloride had apparently evaporated with the solvent. Upon further analysis of previous hydrochloric acid reactions, the ratio of homocubyl alcohol to chloride was also 2:1, assuming the reactions were complete and quantitative. In a reaction of cubylcarbinol (5) with 32 per cent hydrobromic acid in acetic acid, a mixture of homocubyl acetate, homocubyl bromide, and homocubyl alcohol were formed in a ratio of 21 per cent to 45 per cent to 34 per cent, respectively. This reaction took place with two nucleophiles and, therefore, could account for the deviation from the 2:1 alcohol 6 to nucleophilic product ratio.

TABLE 1

REACTIONS OF CUBYLCARBINOL WITH VARIOUS STRONG ACIDS UNDER A VARIETY OF CONDITIONS

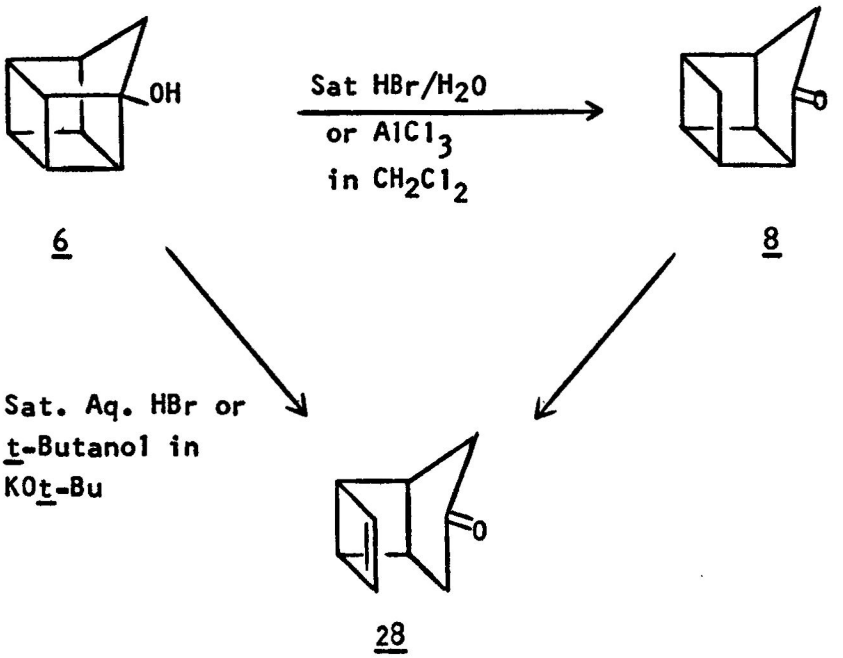
Reaction Conditions	Yield % Homocubyl Alcohol	Yield % Substituted Product
48% HBr (aqueous)[5]	66%	33%
CH_2Cl_2 saturated with HBr	66%	34%
36% HCl (aqueous)	69%	31%
23% HCl (aqueous)	67%	33%
MeOH saturated with HCl	68%	32%
CF_3COOH	71%	29%

It should be pointed out here that the alcohol and halide are not convertible under the reaction conditions.

Internal return of the leaving group dominates the rearrangement of the cubylcarbinyl system. Similar observations have been reported by Dauben,[10] who showed the absence of O^{18} scrambling, when O^{18} labeled bicyclo [2.2.0] hexane-1-methyl-p-nitrobenzoate was solvolyzed to give 1-norbornyl-p-nitrobenzoate.

Treatment of homocubyl alcohol with aluminum chloride and methylene chloride afforded a product tentatively identified as ketone 8. When the alcohol 6 was treated with 48 per cent aqueous hydrobromic acid further saturated with hydrobromic acid, the resulting product showed nuclear magnetic resonance and infrared spectra that coincided with the spectra obtained from the aluminum chloride reaction (ir ; λ= 5.75 μ; nmr - several multiplets between δ= 4.0 and 2.0 ppm). Finally, an attempt was made to isomerize the homocubyl alcohol (6) to the homocubyl ketone 8. Refluxing with potassium hydroxide and potassium methoxide for extended periods produced no results. Consequently, alcohol 6 was treated with potassium t-butoxide in t-butanol. Refluxing at 95°, no matter what the length of time, afforded little ketone 8. When the mixture was refluxed in a sealed tube at 147° for 44 hours, a ketone suspected to be tricyclo [4.3.0.$0^{2,5}$] 3-nonene-8-one (28) was obtained. The infrared spectrum showed a carbonyl absorption at 5.75 μ. The nuclear magnetic resonance spectrum showed two hydrogens centered at δ= 7.10 ppm, four hydrogens centered at δ= 2.21 ppm and several multiplets between 3.70 ppm and 2.30 ppm. When homocubyl alcohol was refluxed at 100° in 48 per cent aqueous hydrogen bromide, further saturated with

hydrogen bromide, the product showed similar spectra. From this data (particularly the appearance of vinyl hydrogens in the nuclear magnetic resonance spectrum), it was suspected that the cage was possibly opened under these conditions to produce ketone 28.



The study of the cubylcarbinyl system afforded many interesting results, the most outstanding of which was the fairly constant two to one ratio of homocubyl alcohol to substitution product despite the strength of the acid or the reaction conditions. It was also found that homocubyl alcohol (6) could be homoketonized under both acid and basic conditions to form a ketone believed to be homocubyl ketone (8). This ketone could be opened up under both acid and basic conditions to form the isomer tricyclo[4.3.0.0.$0^{2,5}$] -3-nonene-8-one.

Numerous possibilities for further study were unfolded. Among these

are the study of the nature of the cubylcarbinyl acetate (27) and the homocubyl acetate (26), the isolation and characterization of both of the isomeric ketones and the chemistry of the homoenolate anions.

EXPERIMENTAL

Infrared spectra were recorded on a Beckman IR-5A spectrophotometer and calibrated against the 6.24 μ band of a polystyrene film. Unless otherwise specified, carbon tetrachloride was used as the solvent for the infrared spectra. Only the most prominent absorption bands in the spectrum are listed. Nuclear magnetic resonance (nmr) spectra were taken on a Varian Associates A60-A spectrometer using carbon tetrachloride or deuteriochloroform solutions. Chemic shifts (δ) are reported in parts per million downfield from internal tetramethylsilance. Melting points were made using a Thomas-Hoover melting point apparatus and are corrected.

Removal of solvent in vacuo or at the flash evaporator refers to evaporation using an all glass Buchler rotary evaporator. Alcoa and Fisher activated alumina was used for column chromatography.

Cubylcarbinol (5).--Cubanecarboxylic acid (23, 500 mg, 3.38 mm), in 17 ml of anhydrous ether was added dropwise to a stirred slurry of 275 mg (7.45 mm) of lithium aluminum hydride in 27 ml of anhydrous ether. The mixture was refluxed for 1.5 hrs in a 50-ml three necked flask equipped with reflux condenser, dropping funnel, and a glass stopper. To quench the reaction, 0.5 ml of water, 0.5 ml of aqueous sodium hydroxide (15 per cent) and 1.5 ml of water were added. The solids were filtered and the solution was washed with 3 volume per cent sulfuric acid, 5 per cent aqueous sodium carbonate, water and saturated brine. The organic layer was dried over sodium sulfate, and the solvent was

removed at the flash evaporator. The reaction afforded 504 mg of crude cubylcarbinol (5). The product was recrystalized from pentane to yield 453 mg (98 per cent) in three crops; mp 64-65°; nmr (CCl_4) δ= 3.92 (s,7H), 3.61 (s, 2H), 3.55 ppm (s,1H); ir (CCl_4) λ= 3.0 (broad, OH), 9.84, 10.05 μ.

Attempted Isomerization of Cubylcarbinol (5) in Benzene.--Into a 50-ml round bottomed flask equipped with a reflux condenser was placed 100 mg of cubycarbinol (5) and 5 ml of benzene. The mixture was refluxed for 2 hrs and checked by infrared spectroscopy. Since no change had occurred, the reaction was continued for 16 hrs. After this time there was no change in the infrared spectrum. p-Toluenesulfonic acid (10 mg) was added. The mixture was refluxed for 2 hrs and then for an additional 16 hrs with no change occurring (infrared analysis).

Reaction of Cubylcarbinol (5) with 48 per cent Aqueous Hydrogen Bromide. Production of Homocubyl Alcohol (8) and Homocubyl Bromide (7).--Into a 25-ml round bottomed flask equipped with a reflux condenser was placed 43.42 mg (0.32 mm) of cubylcarbinol (5) and 2 ml of 48 per cent aqueous hydrogen bromide. The mixture was refluxed for 2 hrs, then cooled and diluted with 10 ml of water and 10 ml of ether. The aqueous layer was drawn off and extracted with ether. The organic phases were combined and drawn off and extracted with ether. The organic phases were combined and washed with 50 ml portions each of 5 per cent aqueous sodium carbonate, water and saturated brine, and then dried over sodium sulfate. The solvent was evaporated in vacuo to yield 49.74 mg (100 per cent) of a mixture of homocubyl ketone (8), homocubyl bromide (7) and homocubyl alcohol (6); ir (CCl_4) λ= 3.10 (OH), 5.80 μ (C=O): nmr (CCl_4) δ= 3.70, δ= 1.90 (ppm). The products were reacted under the

same conditions described above to give what was presumed to be homocubyl ketone (8) and homocubyl bromide (7); ir (CCl_4) λ = 5.75 (C=O) μ; nmr (CCl_4) δ = 3.70 - 2.0 (ppm).

Reaction of Cubylcarbinol (5) with Concentrated Hydrochloric Acid. Formation of Homocubyl Alcohol (6) and Homocubyl Chloride (25).--Cubylcarbinol (5, 100 mg, 0.745 mm) and 20 ml of concentrated hydrochloric acid were placed in a 25-ml round bottomed flask. The solution was stirred for 1 hr at room temperature, then diluted with water. A precipitate was formed during the reaction, but this was easily dissolved in ether. The aqueous layer was drawn off and extracted three times with 20-ml portions of ether. The organic layers were combined and washed with 50-ml portions of 5 per cent aqueous sodium carbonate, water and saturated brine. After the organic layer was dried over sodium sulfate the solvent was removed at the flash evaporator. The reaction yielded 93 mg of chloride 25 and alcohol 6 in a ratio of slightly greater than 3:1 alcohol: nmr (CCl_4) δ = 4.0 (s,1H), 3.32 (m, 7H), 1.80 (d, 2H, J = 1.3 Hz).

Reaction of Cubylcarbinol (5) with Acetic Acid.--Into a 25-ml round bottomed flask equipped with a reflux condenser were placed 50 mg (0.383 mm) of cubylcarbinol (5) and 2 ml of glacial acetic acid. The solution was refluxed on a steam bath for 1 hr, then cooled and diluted with water. Ether was added, the aqueous layer was drawn off, and extracted 3 times with 30-ml portions of ether. The organic layer was washed with 5 per cent aqueous sodium carbonate, water, brine, and then dried over sodium sulfate. The solution was concentrated giving 48.73 mg of crude product. The product was identified as starting material 5 and cubylcarbinyl

acetate (27).

The product was then placed in the same reaction vessel, and 1 ml of acetyl chloride was added. There was an immediate reaction. The mixture was refluxed for 1 hr and then treated as indicated above. The reaction afforded 40 mg (80 per cent) of a mixture of three products: equal amounts of homocubyl alcohol (6) and homocubyl acetate (26), and a small amount of the cubylcarbinyl acetate (27); nmr (CCl_4)δ = 3.73 (s), 3.61 (s), 3.49 (m), 3.95 (m), 200 ppm (s), and 1.79 (d, 2H), J = 1.2 Hz) ppm.

Cubylcarbinyl Acetate (27).--Acetyl chloride (2 ml) was dissolved in 5 ml of anhydrous ether and placed in a 50-ml round bottomed flask equipped with a drying tube. The flask was immersed in an ice bath, and then 2 ml of pyridine (distilled and stored over potassium hydroxide) were added. A salt formed immediately. The mixture was stirred magnetically while 100 mg (0.745 mm) of cubylcarbinol (5) dissolved in 5 ml of anhydrous ether were added dropwise. This mixture was stirred at 0° for 1 hr, then poured over ice, and filtered by gravity. The cooled filtrate was washed with 3 volume per cent sulfuric acid, 5 per cent sodium carbonate, water and saturated brine. The solution was dried over sodium sulfate and the solvent was evaporated in vacuo. The yield was 136 mg (100 per cent) of cubylcarbinyl acetate (27); nmr (CCl_4) δ = 4.20 (s, 1H), 3.95 (m, 7H), and 2.00 ppm s, 3H); ir (CCl_4)λ = 3.38 5.75 (C=O), 8.10 (broad) μ.

Homocubyl Acetate (26).--Into a 50 ml flask were placed 136 mg (0.775 mm) of cubylcarbinyl acetate (28) and 3 ml of trifluoroacetic acid. The mixture was stirred for 5 min, and a nuclear magnetic resonance

spectrum was taken; nmr (CCl_4) δ = 3.49 (broad t,5H), 3.18 (m,2H), 2.2 (s,3H), and 2.12 ppm (d,2H). The solution was evaporated in vacuo and then dissolved in ether. The organic solution was washed with 5 per cent sodium carbonate, water and saturated brine, then dried over sodium sulfate, and evaporated in vacuo. Th yield was 125 mg (92 per cent); ir (CCl_4) λ = 3.38, 5.75 (ester C=0), 8.10 (broad, $CH_3C(=O)O$) μ.

Reaction of Cubylcarbinol (5) with 23 per cent Aqueous Deuterium Chloride.--Cubylcarbinol (5, 46.98 mg, 0.35 mm) was added to 2 ml of 23 per cent deuterium chloride in deuterium oxide and heated at 60° for 23 hrs in a nuclear magnetic resonance tube. Nuclear magnetic resonance spectra were taken periodically to check the progress of the reaction. Nothing could be gleaned from the spectra, however. During the course of the reaction a substance was found to be oiling out in the tube. The solution was dissolved in water and extracted with ether. The organic layer was washed with 5 per cent aqueous sodium carbonate, water and saturated brine. It was dried over sodium sulfate and evaporated in vacuo to yield 35.38 mg (72.7 per cent). A nuclear magnetic resonance spectrum of the product showed the alcohol 6 in 10:1 ratio over chloride 25. Calculations demonstrated that 32.38 mg of homocubyl alcohol had been produced. Thus 67.5 per cent of cubylcarbinol (5) was consumed in producing the alcohol 6, coinciding with a 2:1 ratio of alcohol 6 over chloride 25.

Homocubyl Alcohol (6).--A 50-ml three necked flask was equipped with a reflux condenser, dropping funnel, and stopper. A solution of 125 mg (0.714 mm) of 7 in 10 ml of anhydrous ether was added dropwise to a magnetically stirred slurry of 115 mg of lithium aluminum hydride and 15 ml

of anhydrous ether. The mixture was refluxed for 4 hrs and then quenched by adding 0.25 ml of water, 0.25 ml of 15 per cent sodium hydroxide and 1 ml of water, in that order. The white solids were filtered, and the solution was concentrated in vacuo. The product was recrystallized from pentane to give 89 mg (93.5 per cent in two crops); nmr (CCl_4) δ = 3.29 (m,8H), 1.79 (d, 2H, J = 1.2 Hz) ppm; ir,λ= 3.00 (broad, OH), 3.35 7.70, 7.98 (wk), 8.09 (sh), 8.34 (sh), 8.39 (wk), 9.30 (broad 2k) μ.

Reaction of Cubylcarbinol (5) with Hydrochloric Acid in Methanol. Production of Homocubyl Alcohol (6) and Homocubyl Chloride (25).--Into a 50-ml round bottomed flask equipped with a drying tube were placed 42.41 mg (0.315 mm) of cubylcarbinol (5) and 2 ml of methanol saturated with hydrochloric acid at 0°. The solution was stirred for 1 hr at room temperature. The solution was diluted with water, and added to 50 ml of ether. The aqueous phase was removed and extracted with ether. The organic phases were combined and washed with 5 per cent sodium carbonate, water and brine. The solvent was removed in vacuo to give 29.10 mg (69 per cent) of homocubyl alcohol (6); nmr (CCl_4) δ= 3.82 (S, 10H), 3.32 (m, 7H), 1.80 (d, 2H, J = 1.3H) and 2.10 (d, 2HJ=1.3 Hz) ppm.

Reaction of Cubylcarbinol (5) with Hydrogen Bromide in Methylene Chloride.--Into a 50-ml round bottomed flask equipped with a drying tube were placed 42.72 mg (0.318 mm) of cubylcarbinol (5) and 2 ml of methylene chloride in which gaseous hydrogen bromide had been bubbled for 20 min at 0°. The mixture was stirred for 1 hr. Water and methylene chloride were added and the methylene chloride layer was drawn off. The aqueous layer was extracted with methylene chloride. The organic layers

were combined and washed with 5 per cent sodium carbonate, water and brine. The dried solution was concentrated in vacuo. The yield, a 2:1 mixture of alcohol 6 and bromide 7, was 43.43 mg (90 per cent); nmr (CCl_4) δ = 3.32 (m, 17H), 2.1 (d, 2H, J = 1.3H_z), 1.80 (d,2H, J=1.3H) ppm.

Reaction of Homocubyl Alcohol (6) with 48 per cent Aqueous Hydrogen Bromide.--Homocubyl (6, 26.3 mg, 0.196 mm) and 2 ml of 48 per cent aqueous hydrogen bromide were placed in a 50-ml round bottomed flask. The solution was stirred for 1 hr and then diluted with water. The aqueous layer was extracted with ether. The etheral layer was washed with 5 per cent sodium carbonate, water and saturated brine. The solution was dried and evaporated in vacuo. The yield was quantitative and the nuclear magnetic resonance spectrum showed no change.

Homocubyl Ketone (8) Homoketonization of Homocubyl Alcohol (6).--Method A: In a sealed tube were placed 12.43 mg (0.093 mm) of homocubyl (6) and 50 mg of potassium t-butoxide in 10 ml of t-butyl alcohol (distilled at 82° and stored over molecular sieves). The mixture was heated at 148° for 17 hrs. The cooled tube was emptied and rinsed in water. The diluted solution was added to 100 ml of anhydrous ether and acidified with 6 N aqueous hydrochloric acid. The aqueous layer was drawn off and extracted with ether. The organic layers were combined and washed with 5 per cent aqueous sodium carbonate, water and brine. The solution was dried and concentrated in vacuo; ir (CCL_4) λ = 5.75 μ (C=0); nmr (CCl_4) δ = 4.00 - 2.00 ppm (m). The reaction afforded 14.26 mg (114 per cent) crude ketone 8.

Method B: Into a 50-ml round bottomed flask equipped with a drying

tube were placed 11.54 mg (0.086 mm) of cubylcarbinol (5) and 2 ml of methylene chloride. A catalytic amount (10 mg) of aluminum chloride was added. The mixture was stirred for 1 hr, then diluted with water. The organic layer was removed, and the aqueous layer was extracted with methylene chloride. The organic phases were washed with 5 per cent aqueous sodium carbonate, water, brine. The dried solution was concentrated in vacuo. The crude yield was 12.03 mg (105 per cent) of a mixture of homocubyl alcohol (6) and homocubyl ketone (8); ir (CCl_4) λ = 5.75 (C=O) μ.

Tricyclo[4.3.0.$0^{2,5}$] 3-nonene-8-one (28).--Method A.--Homocubyl alcohol (6, 14.26 mg, 0.010 mm) was added to 50 mg of potassium t-butoxide in 10 ml t-butyl alcohol in a sealed tube. The mixture was heated for 16 hrs at 150°. The cooled tube was emptied and rinsed with water. The diluted solution was added to 100 ml of anhydrous ether and acidified with 6 N hydrochloric acid. The aqueous layer was drawn off and extracted with ether. The organic layers were combined and washed with 5 per cent sodium carbonate, water and saturated brine. The solution was dried and concentrated to give 13.21 mg (93 per cent) crude ketone 28: nmr (CCl_4) δ = 7.10 (m, 2H), 3.70 - 2.30 (m, 4H) 2.30 ppm (m, 4H).

Method B: Homocubyl alcohol (6, 10.58 mg, 0.079 mm) was placed in a 50-ml round bottomed flask, and 2 ml of saturated hydrogen bromide were added. The mixture was stirred for 1 hr. Water and ether were added. The aqueous phase was withdrawn and extracted with ether. The organic layers were combined, washed with 5 per cent sodium carbonate, water and saturated brine. The dried solution was concentrated in vacuo.

The reaction gave 12.13 mg (116 per cent) of crude material. The nuclear magnetic resonance spectrum showed a mixture of homocubyl alcohol (6) and ketone 8. As a result the product was placed in a 60 ml round bottomed flask equipped with a reflux condenser. Two ml of saturated hydrogen bromide were added. The solution was refluxed for 1 hr, then diluted with water and ether, washed as above, and dried. The dried solution was placed on the flash evaporator and concentrated. The nuclear magnetic resonance and infrared spectra were identical to that obtained in Method A.

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